A REVIEW OF TREATMENT TECHNOLOGIES FOR PERCHLORATE REMOVAL FROM CONTAMINATED WATER

Joseph M. Wong, P.E., DEE
Black & Veatch

2002 CA-NV-AWWA Annual Fall Conference
October 14-17, 2002

What Is Perchlorate?

- An Inorganic Anion (ClO4-) Highly Soluble in Water
- Most Highly Oxidized State (+7) of Chlorine
- NH4ClO4 Is Mostly Used in Rocket Fuels and Explosives
- Other Uses – Nuclear Reactors, Electronic Tubes, Tanning, Fertilizers, etc.

What Are The Concerns Of Perchlorate?

- Contamination of Surface and Groundwater Supplies in CA, NV and UT
- Health Effects:
  - Interferes with Iodine Uptake in Thyroid Gland
  - Disrupts Thyroid Hormone Levels; May Lead to Thyroid Gland Tumors
  - Affects Fetuses of Pregnant Women
- Oregon Study NOEL of 5.2-6.4 ug/kg-day or 180-220 ug/L for Adults
- Draft USEPA Drinking Water Equivalent Level is 1 ug/L
- Proposed Public Health Goal by CA OEHHA is 6 ug/L

Regulatory Status of Perchlorate in Drinking Water

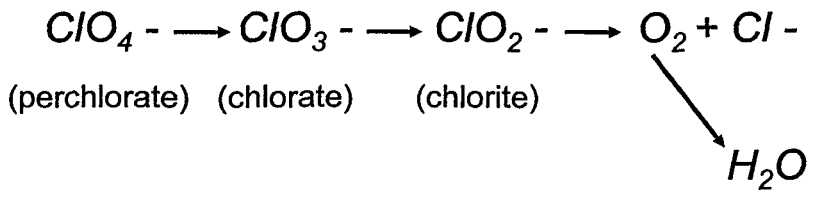
- California DHS Advisory Action Level was 18 ug/L Since 1997
- DHS Revised AL to 4 ug/L on 1/18/2002
- CA SB 1822 to Set Perchlorate Limit by 1/2003 and Enforce by 2004
- Monitored Under EPA UCMR Since 1999
- USEPA Decided Not to Regulate in Summer of 2002
- Other States Have Action Levels Higher Than CA

Potential Treatment Technologies for Perchlorate Removal

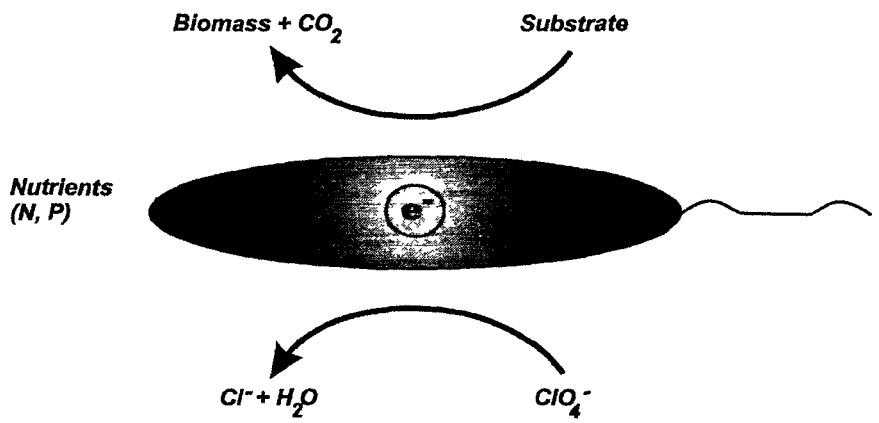
- Biological Treatment
- Modified Granular Activated Carbon Adsorption
- Ion Exchange
- Reverse Osmosis or Nanofiltration
- Electrodialysis or Electrodialysis Reversal
- Capacitive Deionization

Biological Perchlorate Reduction

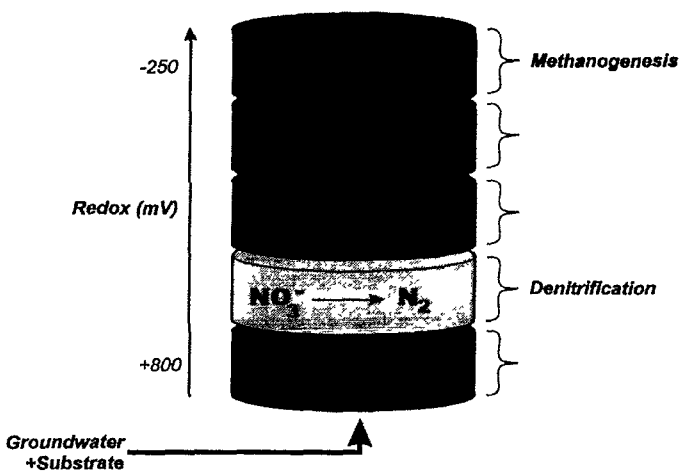
Terminal Electron Acceptor:



Perchlorate



Utilization of Electron Acceptors



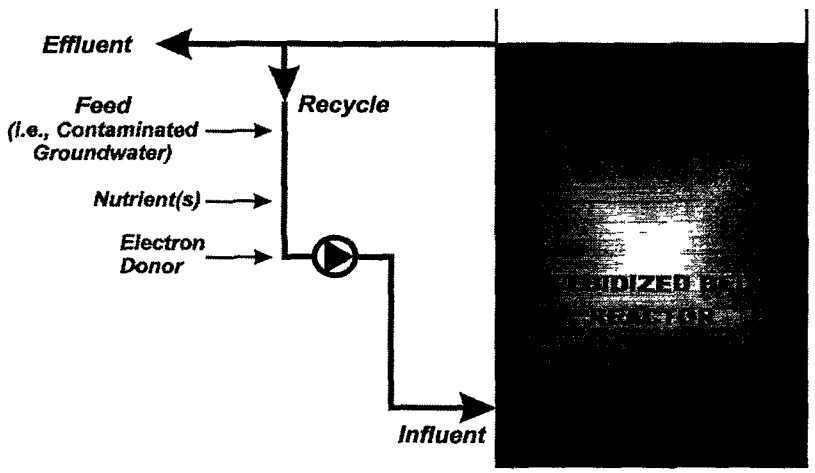
Biological Treatment Processes

- Anoxic Fluidized Bed Reactor
- Biologically Active Carbon
- Hydrogen Gas-Fed Membrane Biofilm Reactor
- Packed Bed Reactor

Fluidized Bed Reactor (FBR)

- Most Established Biological Process for Perchlorate Removal
- 3 Full-Scale Systems for Groundwater Remediation Applications
- Removal to Below Detection in Full-Scale Systems
- Accepted by DHS for Drinking Water Application with Provisions (U.S. Filter/Envirogen)

Flow Diagram of FBR



Aerojet Rancho Cordova FBR Installation

- 4,000 gpm
- Four Reactors
- Ethanol as Electron Donor
- GAC Media

Biologically Active Carbon (BAC)

- Research at University of Illinois
- Has Potential to Reduce Perchlorate at Low PPB Levels
- Reduction Sensitive to Nitrate Concentrations in Water
- Need More Work to Demonstrate Commercial Application

Hydrogen Gas-Fed Membrane Biofilm Reactor

- Patented by Rittmann and Evans of University of Illinois
- Hydrogen Gas as Electron Donor
- Successful Testing Results at 0.3 GPM Pilot System
- New Research Being Supported by USEPA and AWWARF

Packed Bed Bioreactor

- Acetate-Fed Packed Sand Reactor by Logan of Penn State University
- Bench-scale Test Results Successful
- Pilot Testing Being Conducted at Redlands, CA

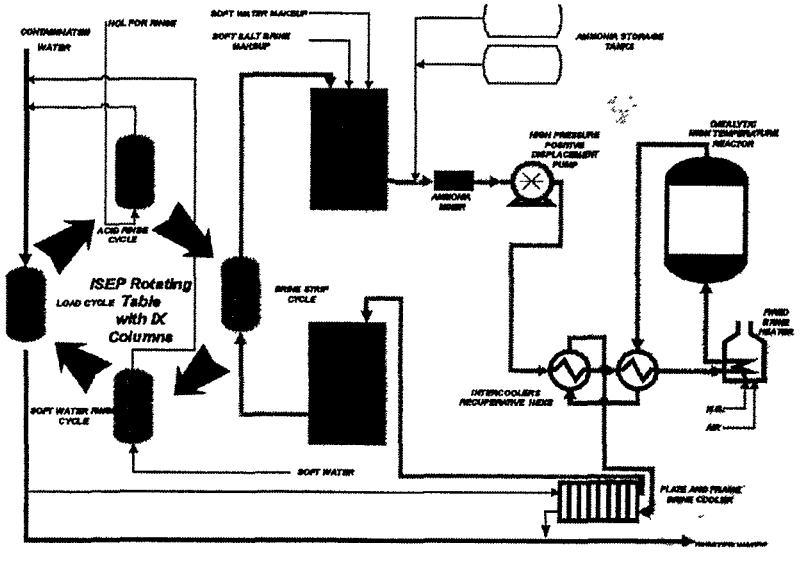
Modified GAC Adsorption

- GAC Can Remove Perchlorate But With Very Limited Capacity
- Redland, CA Study on Existing GAC System Indicated
  - Perchlorate Breakthrough in 3 Weeks
  - TCE and DBCP Breakthrough in 18 Months
  - Extend GAC Life by Modifying GAC With Iron and Oxalic Acid Preloading
- Much More Research Needed

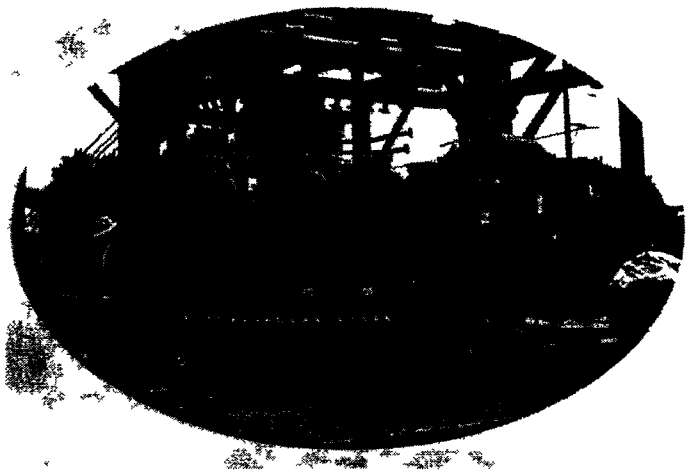
Ion Exchange

- Well Established Technology for Nitrate Removal
- Fixed Bed vs. Continuous Ion Exchange System (ISEP, Higgins Loop)
- Main Concern is Regeneration Waste Management
- Several Full-Scale Systems for Perchlorate Removal in Drinking Water
- Calgon ISEP+TM System For Perchlorate Removal and Destruction
- Research on Biological Treatment of Regeneration Brine

Calgon Carbon Corporation ISEP-PDM Simplified Process Flow for Perchlorate Removal & Destruction



La Puente ISEP Perchlorate Removal System

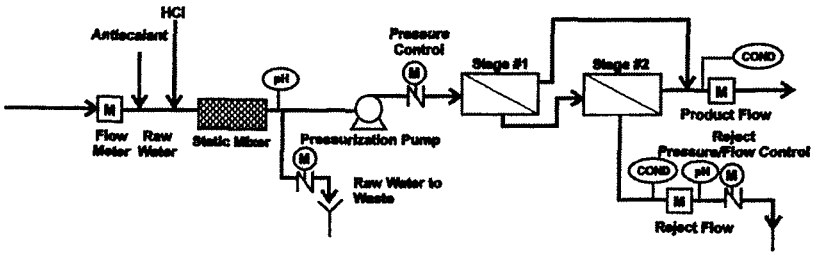


Reverse Osmosis and Nanofiltration

- Pilot Testing of RO/NF Conducted by MWD
- Both RO/NF Effective for Perchlorate Removal to Low Levels
- RO More Effective Than NF at Higher Influent Concentrations
- Large Reject Volume Disposal (15-25%) Is Main Concern
- Not Cost Competitive With Ion Exchange Except When TDS Removal Required

RO/NF System

PROCESS FLOW DIAGRAM OF RO / NF MEMBRANE SYSTEM

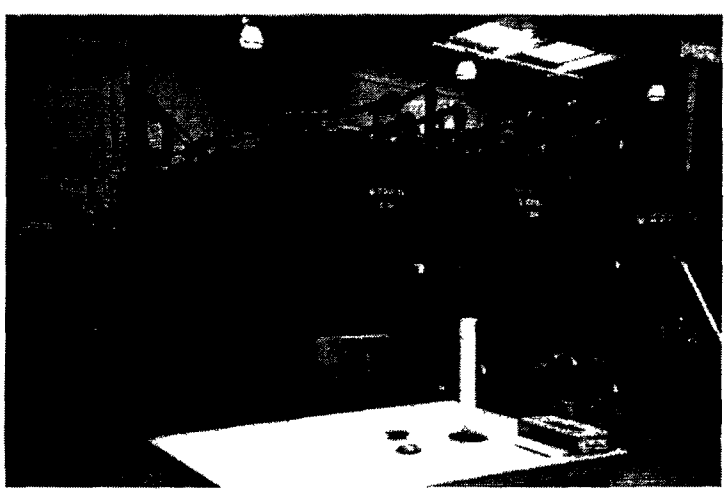


RO and NF Membrane System

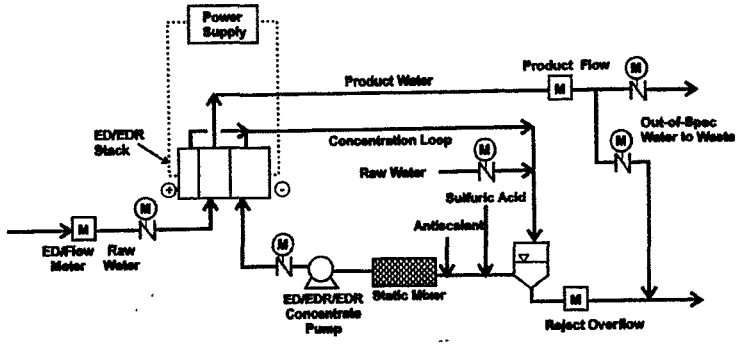
Electrodialysis or EDR

- EDR Pilot Testing Conducted in Magna, Utah
- Well Water High in TDS (1,300 ppm) and Silica (80 ppm)
- EDR Effective in Perchlorate Removal
- Use Multiple Stages to Achieve Desired Quality
- Brine Disposal Is Also A Concern

EDR System



PROCESS FLOW DIAGRAM OF ED / EDR MEMBRANE SYSTEM



ED/EDR Membrane System

Capacitive Deionization

- Carbon Aerogels Used in Capacitive Deionization Process (LLNL)
- Large Surface Area (400-1,000 m2/gm)
- Reduced Perchlorate from 80 mg/L to 10 mg/L in Laboratory Test
- No Testing at Lower Levels
- Not Cost Competitive with Ion Exchange

Conclusions

- Perchlorate Treatment Technologies Are Not Well Established
- Ion Exchange Is Most Established in Drinking Water Application
- Regeneration Waste Disposal Is Major Concern
- Biological Treatment is Promising, But Still Needs More Research
- Advantage of Biological Treatment is Destruction, But Not Concentration
- Membrane Processes Are Effective, But Expensive with Large Waste Stream for Disposal